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EFFECTS OF CAFFEINE AND BENZEDRINE UPON CONDITIONING AND EXTINCTION*

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Although a number of methods are available in measuring the effects of drugs upon the physiological processes concerned with the internal economy of the organism, sensitive indicators of the effects upon behavior are rare. Certain techniques devised for dealing with conditioned responses may be used. In this paper the effects of caffeine and benezdrine upon the rate of elicitation of a conditioned reflex are examined. Two cases are considered: the rate at which a response is elicited (1) when reinforced periodically and (2) when elicited without reinforcement.

SUBJECTS AND TECHNIQUE

Twelve white rats, all males, approximately 120 days old, were used. The apparatus and method were essentially as described by Skinner (references in (2)). The response to be made by the rat was the pushing down of a light horizontal bar or lever. A clock connected the lever and a food magazine in such a way that a response was reinforced with a small pellet of food every four minutes. All responses were recorded in cumulative curves. The experimental periods were one hour long and occurred at the same time each day. At the conclusion of each day's experiments the rats were returned to their living cages and allowed to eat dry food (Purina Dog Chow) for a period of 2 hours. Water was accessible to the animals except when they were in the experimental apparatus.

The drugs were given in .5 cc of physiological salt solution by subcutaneous injection. On the base or control days an equal amount of the salt solution was given. In all cases the drug was given immediately before putting the animal in the apparatus and beginning the experiment.

RESULTS

The results may be stated in general terms as follows:

1. Caffeine increases the rate of pressing the lever both when the response is periodically reinforced every four minutes and also

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after several days of extinction. 2. Benzedrine also increases the rate and after a number of days of extinction will bring it back to the level which obtained under the conditions of periodic reinforcement.

Figure 1 is a graph showing the daily and mean number of responses per hour of four rats which were given 10 mgm. of caffeine sodio-benzoate on the days indicated. The rats had had several weeks of

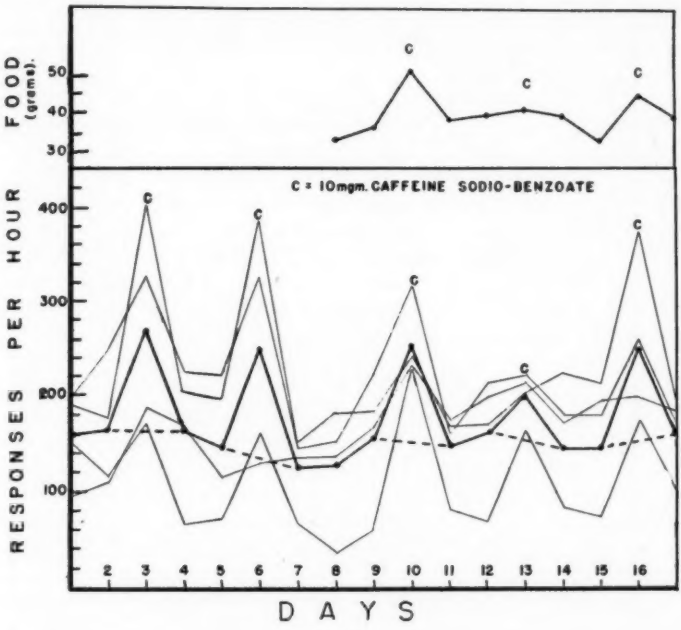

FIGURE 1.

Effects of caffeine upon the rate of responding under periodic reinforcement and upon food consumption. The lower curves show the individual rates (light lines) and the mean rate (heavy line). The upper curve shows the mean food consumption in grams.

periodic reconditioning before the drug was administered. It will be noted that the caffeine without exception increased the mean rate of response over that which obtained on days in which no caffeine was given. On several occasions an individual rat did not increase

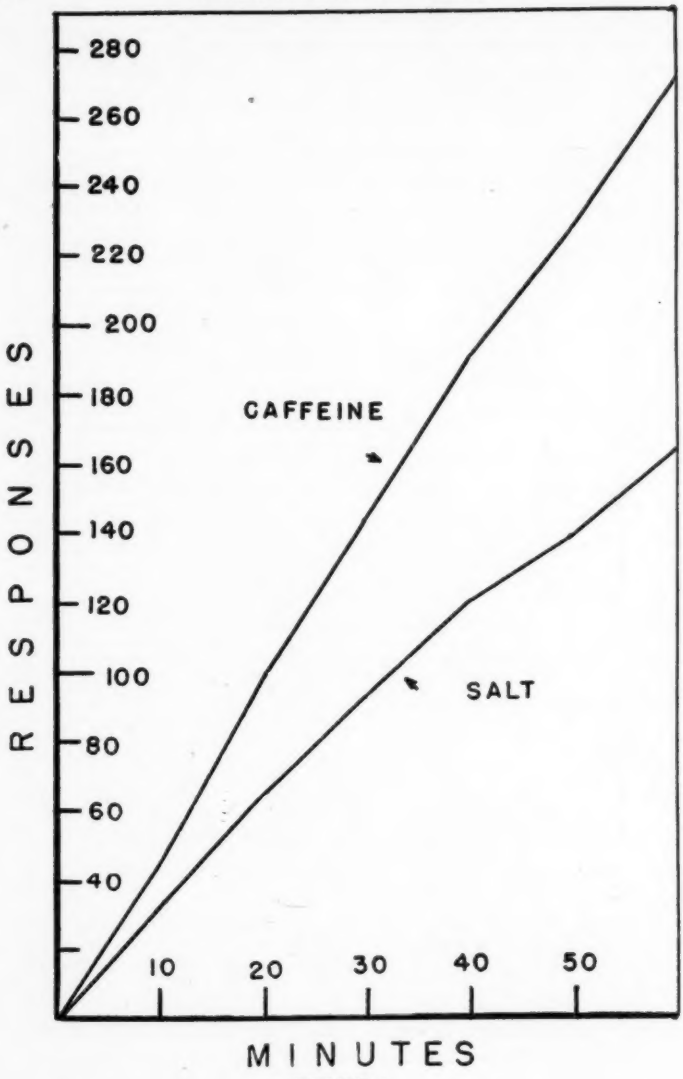

FIGURE 2.

The mean cumulative curve for four rats on the first caffeine day and on the preceding base day when salt was given.

his rate over his base rate. These individual variations in reaction to a drug given under closely controlled conditions are difficult to explain but may be caused by elusive physiological changes which it is at present difficult to bring under control.

On the fourth caffeine day the mean rate did not show so large an increase as had been obtained before. The solution of caffeine was several days old, and it was thought that some deterioration might have taken place. On the last day a new solution was used, and the mean rate returned to its former position. Whether deterioration actually occurred cannot, of course, be decided by this single case.

After the caffeine had been given twice, it occurred to us that the increase in rate might be caused indirectly through an increase in hunger. It has been shown on several previous occasions that the rate of responding is very sensitive to changes in hunger (1) (2). As a check on this possibility the amount of food eaten by each rat following the experimentation each day was determined by weight. The mean food consumption is plotted at the top of Figure 1. It will be noted that there is a close coincidence between the variations in the amount of food consumed and the rate of responding for that day. It is apparent that the caffeine does increase the food consumption and that presumably the rat is hungrier while he is in the apparatus. This would account for some of the effect upon behavior but probably not all (see below).

Since caffeine is given immediately preceding the experiment, it might be supposed that the cumulative curve would be positively accelerated, since some time might be required for the drug to act. Figure 2 gives the mean cumulative curves for four rats for the first caffeine day. It is clear that the curve for caffeine is not greatly accelerated and that the drug must start its action almost immediately. The mean curve for the preceding base day is also given.

If the rats are placed in the box for the same period daily but are given no reinforcement, their rate of responding gradually decreases. This gives the typical curve of extinction. In Figure 3 is shown the extinction curve for the four rats in Figure 1. On the fifth day of extinction caffeine was given. This had the effect of restoring the rate almost to the level prevailing during periodic reinforcement. On the second day following the administration of caffeine there is another rise in the extinction curve as a sort of rebound. Both of these increases are accompanied by corresponding increases in the food consumption as shown in Curve A of Figure 3.

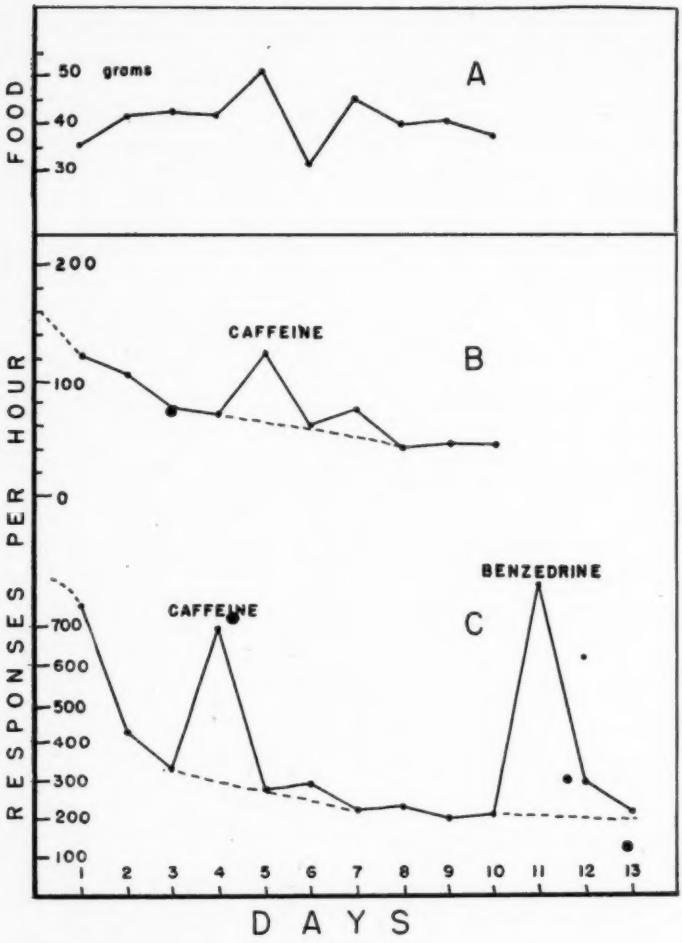

FIGURE 3.

Effects of caffeine and benzedrine upon the rate of responding after several days of extinction. Curve C is the mean curve for a group of 8 rats. Curve B is for a group of four rats. Curve A is the food curve for the rats of Curve B. Dose: caffeine = 10 mgm. of caffeine sodio-benzoate per rat; benzedrine = .5 mgm. of benzedrine sulphate per rat.

Curve C in Figure 3 shows a repetition of the experiment with a group of 8 rats. These rats had also had a large amount of experience in the experimental situation before the extinction was started and gave a much higher constant rate under periodic reconditioning. Here again the caffeine restored the rate almost to its original level and a 'rebound' occurred on the second day following the caffeine. Unfortunately, food records for this group were not taken.

The only explanation that we can give for the secondary rise is that the rat overeats on the caffeine day and, therefore, eats a substandard ration on the following day. The result is that on the third day he is hungrier than normal. However, the same phenomenon does not seem to occur under conditions of periodical reinforcement (see Fig. 1). The rate on the second day following caffeine is not consistently higher in this case, nor does the food curve show the expected rebound.

The attempt to explain the effects of caffeine in terms of hunger changes is weakened by the results of the administration of benzedrine. The second group of animals just mentioned were given .5 mgm. of benzedrine sulphate (a relatively large dose according to human standards) on the 11th day of extinction. Curve C of Fig. 3 shows that the drug produced a complete restoration of the rate of response to the level of periodical reinforcement. Nor does the rate return to its former extinction level on the day following. The reason for this, if significant, is not clear, as the drug is presumably entirely eliminated in the course of a few hours. The results from benzedrine are not consonant with the idea that changes in hunger account for the effects of caffeine, since benzedrine does not increase hunger. On the contrary, as has been shown by Wentink (4), there is a decrease in food consumption after injections of benzedrine.

Discussion

The experiment was suggested by Pavlov's statement that caffeine tends to destroy inhibition and hence to delay extinction. Under the conditions of the present experiment a certain amount of extinction takes place during each four minute interval between reinforcements. Extinction is also represented by the decline in rate on the days when no reinforcement at all is given. Our demonstration of an increased activity might, therefore, be considered to substantiate Pavlov's position. Benzedrine is, in Pavlov's terminology, a much more powerful destroyer of inhibition than caffeine. This drug was, of course, unknown to Pavlov as it has been available only within recent years.

It is not necessary, however, to use the concept of inhibition in interpreting these results. We may just as well say that the effect of either drug is to cause the organism to release energy at a higher than normal rate whether in a state of inhibition or not. The surplus energy is used by the animal in doing what it is accustomed to doing in the situation. According to this view any factor increasing the rate of energy output should result in an increase in the rate of responding—for example, an increase in the oxygen concentration of the air which the animal breathes. If this view is correct, the rate of responding should be increased by such a factor even when the animal is receiving a reinforcement for each response and is not, therefore, displaying 'inhibition.' An experiment on that point might settle the question of the need of the concept of inhibition in interpreting the process of extinction (see 3).

Summary

When a conditioned response in a rat is reinforced periodically every four minutes, caffeine will increase the mean rate of responding to a considerable extent. After several days of extinction, caffeine and benzedrine will restore the rate of responding to that which obtained before extinction began.

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